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Analysis of "A Practical Model for Subsurface Light Transport"

This text describes the mathematical model and application of sub-surface scattering, a technique used in computer graphics and even medical simulations to describe the behavior of a ray of light as it passes through a translucent surface. This behavior is critical to developing technologies such as film, games and medicine, as it accurately describes and models the real-world behavior of light as closely as possible. I chose this topic because I have been actively learning and practicing in the field of computer graphics since my childhood, and since the premise of computer graphics is based entirely in infinite, continuous mathematics as well as discrete, finite computation, it is completely applicable to my field: computer science and game design. The purpose of this text is to inform the reader of a new method of simulating light scattering in surface shading models. This text attempts to convince the reader that the proposed method achieves unprecedented render and computation speeds when compared to other more complex and slower methods. The text is also complete with a mathematical breakdown of each step of the model, as well as numerous images, charts and tables, meant to inform the reader of the model's accuracy, speed, complexity, application. The text itself, although interspersed with the occasional complicated lexis, is fairly readable by a variety of audiences. The text can be read by a mathematician or a physicist to come to a more complete understanding of the theory of subsurface scattering and behavior of light upon hitting a translucent surface. Additionally, it can be read by shader programmers and technical artists to help them develop computer graphics related code and tools. Lastly, the text is even applicable to novices in the field of computer graphics and programming. Although a decent portion of the text is devoted to describing the theoretical and mathematical behavior of light rays, much of it also describes the final results, and compares the algorithm to previous models as well as providing visual comparisons of this lighting model and older, simpler, less sophisticated ones.

This text can be categorized as the product of, and for, a discourse community. By Swales' standards, it fits several categories. In general, the community surrounding computer graphics is largely dedicated to advancements in technology, theory and programming. Although it may seem odd, computer graphics would not exist without programs and languages that make it possible, so code and graphics are inexorably intertwined. This text was produced to appear in SIGGRAPH conference proceedings. It is clearly evident that this text was meant to be dispersed to the computer graphics community at SIGGRAPH and beyond, and the lexis and organization of the text attribute to that greatly. The lexis that appears in this paper includes terms such as "Monte Carlo method," "BRDF" and "BSSRDF," "photorealism," and of course the math itself, which implies the reader must meet an academic criterion, in order to implement the suggested method, or at the very least, fully comprehend the text. When describing the practical applications of this algorithm, the text states,

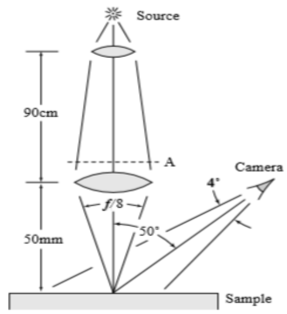
> Subsurface scattering is also important in medical physics, where models have been developed to describe the scattering of laser light in human tissue [6, 8]. In that context, diffusion theory is often used to predict as well as to measure the optical properties of highly scattering materials. We have extended this theory for use in

> computer graphics by adding exact single scattering, support for arbitrary geometry, and a practical sampling technique for rendering. [1(page 1, section 1.1)]

Several unique examples of lexis are presented, such as “subsurface scattering”, “sampling” and “arbitrary geometry”. These terms present additional information to an advanced reader, yet this portion of text also relays significant information regarding the importance of this technique to more novice readers.

Another example of a discourse community is seen when the nature of the article at the SIGGRAPH conference is observed. The authors, their references and contact information is present in the text, and because the method is so intricately described, the implication is that the authors desire for their technique to be implemented, tried and tested by the readers. Although the authors do not make direct statements in the text, it is still obvious that they can be contacted for additional information, further promoting discourse.

The structure of the text pertains to the information it is relaying to the reader. Because the topic is highly technical, the paragraphs, sections, images and data are structured in a specific way that will allow the reader to more fully comprehend the lighting model. The text is comprised of 5 sections, all describing a portion of the lighting model, in an intelligible and logical order. The first section is an abstract and introduction into the field, citing several references to the importance of computer graphics and attributing this lighting model to striving for photorealism and speed. It also explains the faults of previous lighting models leading up to this technique, setting the stage for why this method is preferred or better. The second sections dives into the theoretical math behind the lighting model. It is a step by step mathematical proof, essential a series of equations, which is sequentially simplified into the final equation which represents the lighting model. This sections breaks down every step of the model into its own equation, which is captioned by text that further explains it, as well as images that illustrate the behavior of each portion of the complete model.



(a)

Material	σ_s' [mm^{-1}]			σ_a [mm^{-1}]			Diffuse Reflectance			η
	R	G	B	R	G	B	R	G	B	
Apple	2.29	2.39	1.97	0.0030	0.0034	0.046	0.85	0.84	0.53	1.3
Chicken1	0.15	0.21	0.38	0.015	0.077	0.19	0.31	0.15	0.10	1.3
Chicken2	0.19	0.25	0.32	0.018	0.088	0.20	0.32	0.16	0.10	1.3
Cream	7.38	5.47	3.15	0.0002	0.0028	0.0163	0.98	0.90	0.73	1.3
Ketchup	0.18	0.07	0.03	0.061	0.97	1.45	0.16	0.01	0.00	1.3
Marble	2.19	2.62	3.00	0.0021	0.0041	0.0071	0.83	0.79	0.75	1.5
Potato	0.68	0.70	0.55	0.0024	0.0090	0.12	0.77	0.62	0.21	1.3
Skimmilk	0.70	1.22	1.90	0.0014	0.0025	0.0142	0.81	0.81	0.69	1.3
Skin1	0.74	0.88	1.01	0.032	0.17	0.48	0.44	0.22	0.13	1.3
Skin2	1.09	1.59	1.79	0.013	0.070	0.145	0.63	0.44	0.34	1.3
Spectralon	11.6	20.4	14.9	0.00	0.00	0.00	1.00	1.00	1.00	1.3
Wholemilk	2.55	3.21	3.77	0.0011	0.0024	0.014	0.91	0.88	0.76	1.3

(b)

Figure 5: (a) Measurement apparatus, (b) measured parameters for several materials.

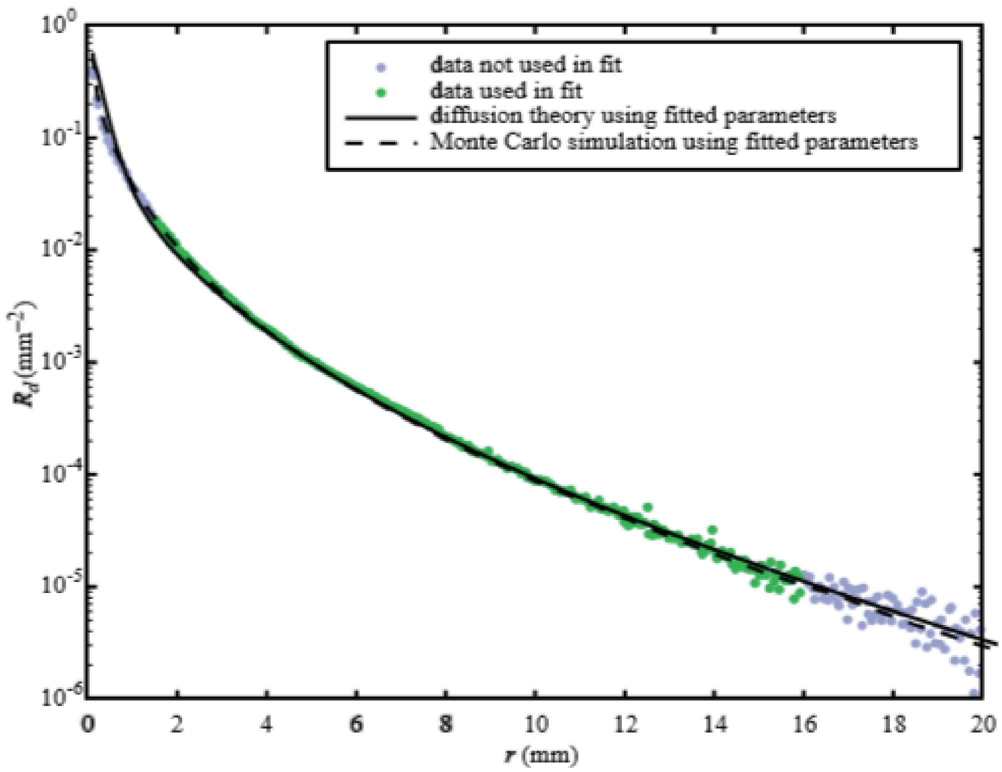


Figure 6: Measurements for marble (green wavelength band) plotted with fit to diffusion theory and confirming Monte Carlo simulation.

The third section focuses on providing data collected through observation to verify, tweak and fine tune the algorithm. The section contains 2 important figures, a data table (figure 5) and a graph (figure 6). The data table presents a juxtaposition of 2 values, one being produced by the algorithm and one collected from real-life experiments. The graph is meant to illustrate the plotting of these values against each other, and matching them up against the values predicted by the algorithm. Both of these figures allow the reader to see the accuracy of the algorithm when compared to real-world data. Ultimately, however, the eye is the final judge in these types of simulations. Section 4 brings the theoretical model into practice, discussing realistic application, limitations, examples and impossibilities. This section brings up the application of this method in a real rendering technique, ray-tracing, and provides more mathematical models and images to allow the reader to implement the technique correctly. This section also provides the first actual image comparison of the results. Figure 8 displays a photo of a block of marble, and a photorealistic rendering of the same block in the same lighting conditions, using the algorithm described earlier. The last section finalizes the results of the lighting model by providing renderings of a specific 3d model on a specific machine, whose specifications are described in the text. This portion of the text is engaging and promotes participation by providing the values used to achieve the effect:

> Figure 9 shows several different simulations of subsurface scattering in a marble bust (1.3 million triangles) illuminated from behind. The BSSRDF simulation mostly matches the appearance of the full Monte Carlo simulation, yet is significantly faster (5 minutes vs. 1250 minutes). The hair at the back of the head is slightly darker in the BSSRDF simulation; we believe this is due to the forced $1/\sigma 0$ t distance in the diffusion approximation. A similar rendering was done using photon mapping in [5] in roughly 12

minutes (scaled to the speed of our computer). However, the photon mapping method requires a full 3D-description of the material, it requires memory to store the photons 1(page 6, section 5)

If the reader is capable of implementing the model via code, he can render his own results and compare. The provided images show a render of a traditional shading model, the shading model described in the text, and a classic, sophisticated shading model that achieves the same result. The point of the comparison is the demonstrate how the lighting model described in the text is superior to the other techniques due to an equal or better perceived visual result yet dramatically better rendering speed. This close reading examines several aspects of the text that relate to a discourse community, yet still make the text understandable to newcomers. The use of specific lexis such as “BSSRDF” and “Monte Carlo Simulation” are necessary for advanced readers to make conclusions of the presented algorithm, but the given render speeds and methods still present neophytes with a simple understanding of the algorithm’s performance. The last image in the text provides an image of a glass of milk using the same 3 lighting techniques as the previous image.

This document is short, yet well written. It provides information for both high level and low level readers, which I feel is lacking from many textbooks and writings in my field. From my experience, the texts available to me are either too high level to be of use in practice, or too low level to understand without a high enough academic level. This text achieves the best of both worlds; it is low level enough to be read and implemented in an actual rendering program, and high level enough to be read for the sake of learning about subsurface scattering behavior of light rays and its application and limitations in the real world. During my co-op experience, I did tons of frontend web design, so this documents doesn’t relate in any way. Frontend web development is relatively subjective experience with minimal coding; creating a simulation of this algorithm is a much more intense exercise in programming, it requires knowledge to decipher the math behind the scenes, and the knowledge to implement it successfully. In terms of writing skill, I think my writing skill matches or exceeds the writing in this article, aside from the Mathematical notation. I can read the notation, but when it comes to writing out viable proofs that support my algorithm’s speed and effectiveness, I have a lot of work to do. I need to familiarize myself more with the notation and general terms used in describing the behavior, speed and efficiency of algorithms. Things such as infinite sums, linear algebra and calculus notation, and shader languages. However, when it comes to describing the way the algorithm behaves, I feel very comfortable translating my thoughts and notions to the reader through written text.

Works Cited

1. Jensen, Henrik W., Stephen R. Marschner, Marc Levoy, and Pat Hanrahan. *A Practical Model for Subsurface Light Transport*. Diss. Stanford U, n.d. N.p.: n.p., n.d. Print. Available from: http://www.graphics.stanford.edu/papers/bssrdf/bssrdf.pdf